

# **Distribution, Abundance and Population Structuring of Beaked Whales in the Great Bahama Canyon, Northern Bahamas**

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## **LONG-TERM GOALS**

The long-term goal of this project is to collect baseline data to fill critical data gaps on the population ecology of beaked whales in the northern Bahamas, specifically relating to distribution, habitat use, abundance and population structuring.

## **OBJECTIVES**

The objectives of the three-year study are:

- 1) To use visual survey techniques to document beaked whale distribution and habitat use, and to estimate abundance in the Great Bahama Canyon (Figure 1).
- 2) To use photo-identification techniques to extend an existing photographic catalogue of individual beaked whales, which will be queried to examine the distribution, movements and social affiliations of identified individuals, and to assess abundance using mark-recapture techniques.
- 3) To use remote biopsy techniques to collect skin and blubber samples to contribute to the study of beaked whale diet (through fatty acid, stable isotope and contaminant analyses) and stock structure (using molecular genetic approaches).
- 4) To develop and implement methods of detecting beaked whales using a towed acoustic array, compare visual and acoustic detection rates, and compare detection efficiency of the towed array and the bottom mounted hydrophones at the Atlantic Underwater Test and Evaluation Center.
- 5) To collect baseline data on the distribution and relative abundance of other cetacean species in this area.

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6) To collect photo-identification and biopsy data from other species, notably sperm whales, killer whales and oceanic bottlenose dolphins, as part of an effort to assess abundance, stock structure and diet. Sightings of sea turtles and interesting bird species will be recorded as well.

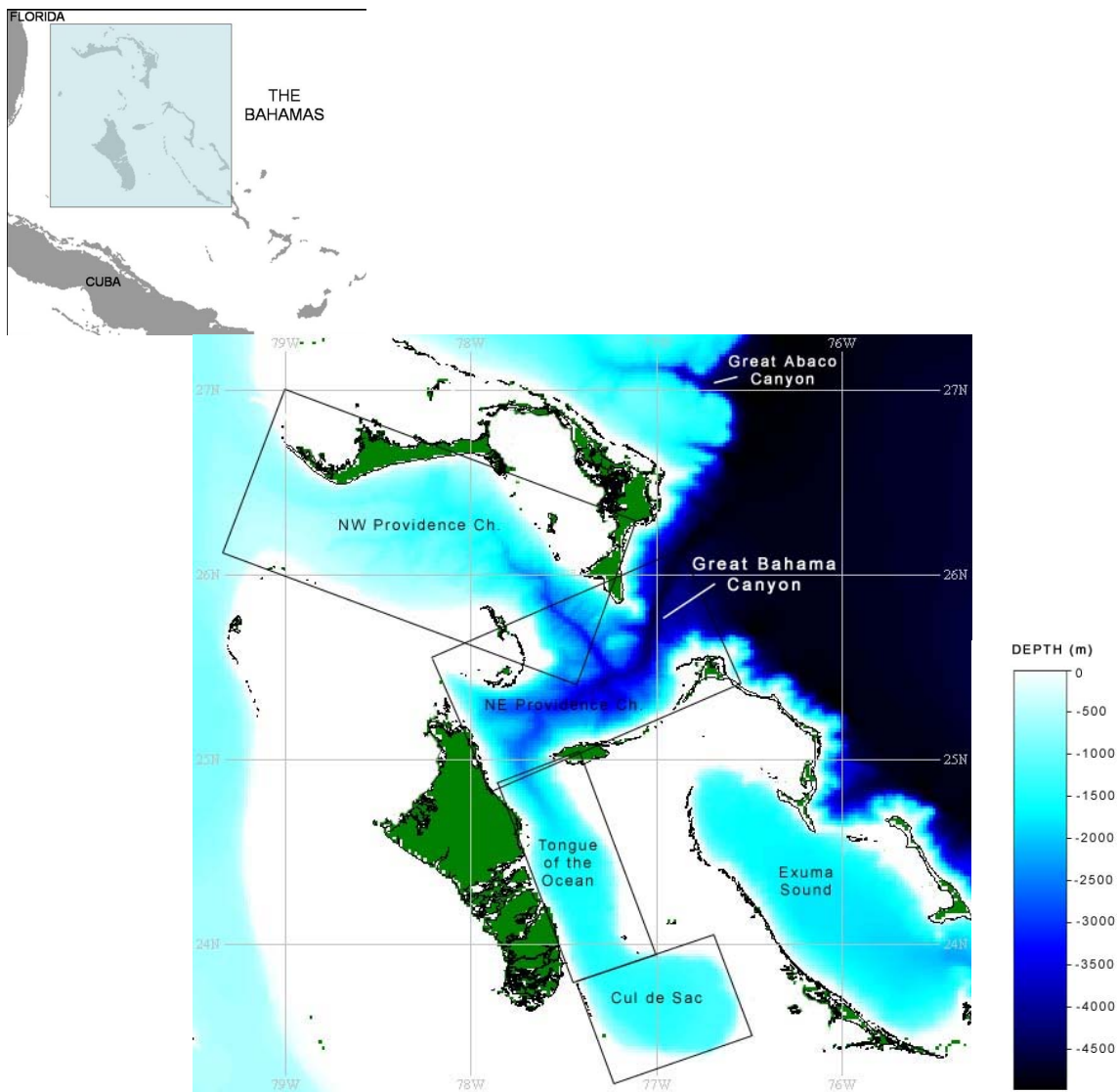
## APPROACH

To accomplish our objectives, the project comprises three different field components in the northern Bahamas (Figure 1). The first component involves three one-month ship-based visual and acoustic surveys of the Great Bahama Canyon to determine the distribution of beaked whales and use distance sampling techniques to estimate their abundance. These cruises will occur during different seasons, with two cruises in 2007 (May and October) and one cruise in May 2008.

The second field component involves two one-month shore-based efforts using a smaller vessel with focused work on photo-identification and biopsy sampling of beaked whales in “hot spots” found during the cruises as well as areas outside the Great Bahama Canyon (i.e. Exuma Sound and Great Abaco Canyon) to contribute towards an assessment of population structuring within the Great Bahama Canyon. The third field component comprised training exercises. Prior to the first ship survey, the scientific team prepared by participating in a NOAA cruise in Alaska which involved the use of similar field methodologies and by developing biopsy techniques appropriate for use on beaked whales. The biopsy work took place off southwest Great Abaco Island, Bahamas which is where researchers from the Bahamas Marine Mammal Research Organisation (BMMRO) have been conducting studies on beaked whales since 1997 (for more information on BMMRO’s study, see Claridge 2006).

The first of the three ship surveys took place aboard the *Odyssey*, a 28 m research sailing vessel, which was chartered from May 5<sup>th</sup> – June 9<sup>th</sup>, 2007. Standardized line-transect techniques were used to assess patterns of distribution and relative abundance using a survey designed by Dr. John Durban (NOAA Fisheries). The Great Bahama Canyon was divided into four survey grids, with each grid running in the same orientation as a deep ocean channel (NE Providence Channel, NW Providence Channel, Tongue of the Ocean and the Cul de Sac) as shown in Figure 1. Transect lines were randomly placed within the four rectangular strata using a saw-tooth (zig-zag) pattern inside each grid to allow equal area coverage and ensure that the track lines randomly sampled the study area. Because these strata were slightly different sizes, the proportional area of each stratum was calculated and thus the length of track line needed in each to ensure equal area coverage. The angle of the saw-tooth track lines was then determined to meet this track line requirement.

For placing of track lines, a random start-point along the shortest side of each stratum was chosen, and a randomly chosen survey direction (up or down). The start point was chosen by dividing the width of each stratum into 1nm sections, and then using a uniform random number generator to select the increment at which to start in each stratum (in reference to the top left corner). The direction was chosen by using a U(0,1) random generator and choosing “up” if the number is >0.49. New track-lines will be re-drawn for survey 2 in October 2007 and survey 3 in May 2008.



**Figure 1. The Great Bahama Canyon branches into Northwest Providence Channel and from Northeast Providence Channel south into Tongue of the Ocean and the Cul de Sac. The canyon reaches depths of more than 4000m. The four survey grids are shown.**

Diane Claridge (Bahamas Marine Mammal Research Organisation) served as the Chief Scientist for the *Odyssey* cruise. Protocols for data recording were based on previous line transect surveys (e.g. Barlow, SWFS, Zerbini *et. al* 2006) and were adapted to the survey as appropriate. During the survey, there was a scientific team of seven observers rotating through positions as observers and a data recorder. Two primary observers were positioned on opposite sides of the primary observation platform (5m height above sea level) and used Fujinon 25 X 150 bigeyes binoculars to scan from 90° on their side and overlap 10° on the other side to provide greater coverage of the track line. If weather conditions made the use of Big Eyes too difficult (e.g. broadside swell), observers used 7 X 50 reticule binoculars. A third observer was responsible for scanning the centerline (track line) and searching the near view, and was positioned either on the primary platform or on the secondary observation platform (9m above sea level on the ship's foremast) with 7 X 50 binoculars.

A fourth person was used as a recorder to input sightings and environmental conditions into data-logging software on a PC and to monitor for acoustic detections. The data recorder was in the pilot house and communicated with the observers with handheld VHF radios. This 4-person team had 30-minute shifts in each position, in order to minimize observer fatigue. At times there was an additional independent observer positioned on the secondary platform or the crow's nest to help determine differences in the ability of each primary observer to successfully detect animals. Reticule binoculars were used to estimate distance to sightings, and the bearing ring on the bigeyes or fixed angle boards were used to record the bearing to the sighting relative to the path of the ship. The *Odyssey* traveled at a speed of approximately 8 knots during the visual and acoustic surveys.

Upon sightings, the *Odyssey* broke off the transect line for a close approach on the group when necessary to confirm species identification and to estimate group size. Closing mode was adopted for all sightings of beaked whales and sperm whales, and a 5.5 m rigid-hulled inflatable boat (RHIB) was deployed for photo-ID and biopsy sampling. The RHIB team consisted of 4 people, leaving 3 people on the *Odyssey* to help track the group visually and acoustically. After each encounter, the *Odyssey* returned to the transect line by converging back to the track line to avoid resightings of the same animals. Sightings which occur during passage back to the transect line were recorded as 'off effort'.

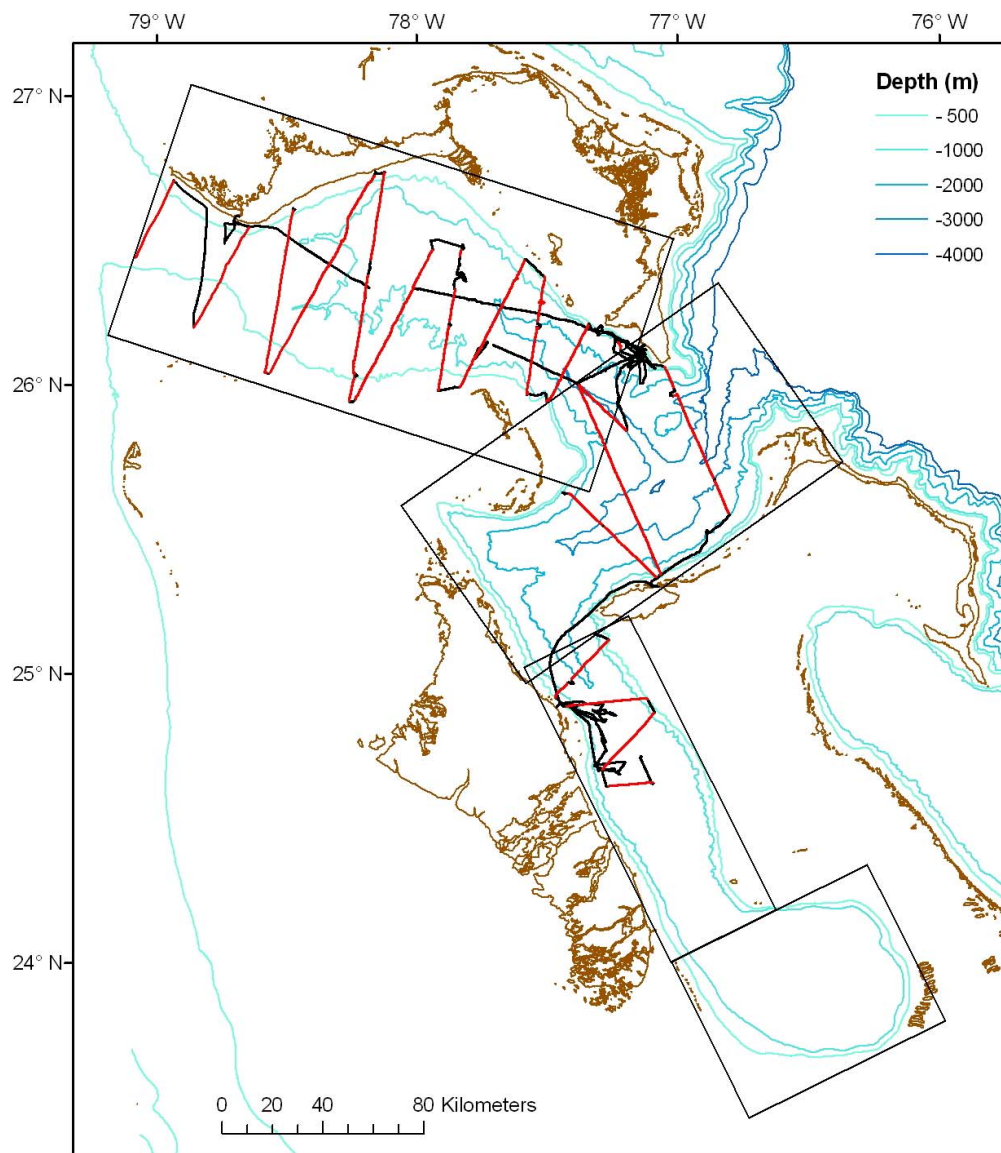
Drs. Jonathan Gordon and Doug Gillespie (Sea Mammal Research Unit) constructed the towed hydrophone array and Dr. Gordon joined the cruise to oversee the acoustic survey. The hydrophone consisted of 2 arrays: one at 200 m and one at 400 m, each with 4 elements. Continuous recordings were made at a sampling rate of 192 kHz from the towed hydrophone arrays during line transect surveys as well as during times when visual observers were off effort (e.g. at night). A beaked whale click detector and classifier was developed within Rainbow Click and PAMGUARD and this was both run in real time and used to analyze recordings to pick out beaked whale click trains. Some of this effort was done in conjunction with Dr. Dave Moretti (Naval Undersea Warfare Center) and his team monitoring bottom-mounted hydrophones at the AUTECH Tongue of the Ocean navy range to compare detections of beaked whales. [This report will not include results from the acoustic portion of the survey.]

## **WORK COMPLETED**

Before the first cruise, three biopsy training sessions took place based from BMMRO's research center on Great Abaco Island. A 6.5 m RHIB was used during 13 days of training between October 2006 and May 2007. This effort covered 628 km (340 nmi) and the team spent 73.9 hours on the water. There were 21 sightings of cetaceans off the southwest coast of Abaco Island, including 6 beaked whale sightings. Two different remote biopsy techniques were tested during 11 biopsy trials: an air rifle and a crossbow. The protocol chosen for the cruise was to use the air rifle at 10 m range and the crossbow if the target animal was more than 10 m away.

During the 36-day cruise on board the *Odyssey*, twelve days were spent at sea conducting visual and acoustic surveys. A total of 1791 km (968 nmi) of visual survey effort was completed, which included 899 km (480 nmi) run along randomly placed transect lines. While almost all of the transect lines in the NW Providence grid were completed, only some were completed in NE Providence and Tongue of the Ocean and none from the Cul de Sac grid (Figure 2). The combination of various mechanical problems with the *Odyssey* and inclement weather hampered efforts to complete the transect lines in all grids as the number of days at sea was below the expected number of 20 days. Due to these constraints, although the goal was to run transect lines in sea states of Beaufort 3 and less, seven transect lines were

run in sea states greater than Beaufort 3 and up to Beaufort 5, which limited sighting opportunities, especially for beaked whales.



**Figure 2. Ship track lines recorded during the Odyssey cruise in May-June 2007. Red lines represent transect lines run in a saw-tooth pattern across the survey grids, showing that almost all of the transect lines were completed in the NW Providence grid while only some or none were completed in the other three grids. Black lines represent the track of the ship during all other types of survey mode. These include on-effort transits between transect lines, on-effort searches in the lee shore of Abaco Island, off-effort tracks towing the array over AUTECH hydrophones, off-effort tracks when in closing mode with animals, and on and off effort daytime passages to and from port.**

During the *Odyssey* cruise, there were 37 marine mammal sightings, comprising 8 different species. There were 9 sightings of beaked whales; six of which were Blainville's beaked whale (*Mesoplodon densirostris*), one sighting of Cuvier's beaked whale (*Ziphius cavirostris*) and there were 2 sightings of unknown Ziphiids. Table 1 summarises the sightings data for each species. Blainville's beaked whale

(*Mesoplodon densirostris*) was the most frequently sighted species and was found in average group sizes of 3-4 whales (median = 3.5, range = 3-5). A total of one hundred and fifty-six animals of all species were seen. During beaked whale encounters, biopsy attempts were made two times, resulting in the successful collection of one tissue sample. An additional sample was collected two days after the cruise ended. The skin and blubber cores were sub-sampled and stored in liquid nitrogen and/or preservative and shipped to the Northwest Fisheries Science Center (Seattle, WA) for genetic and diet analysis.

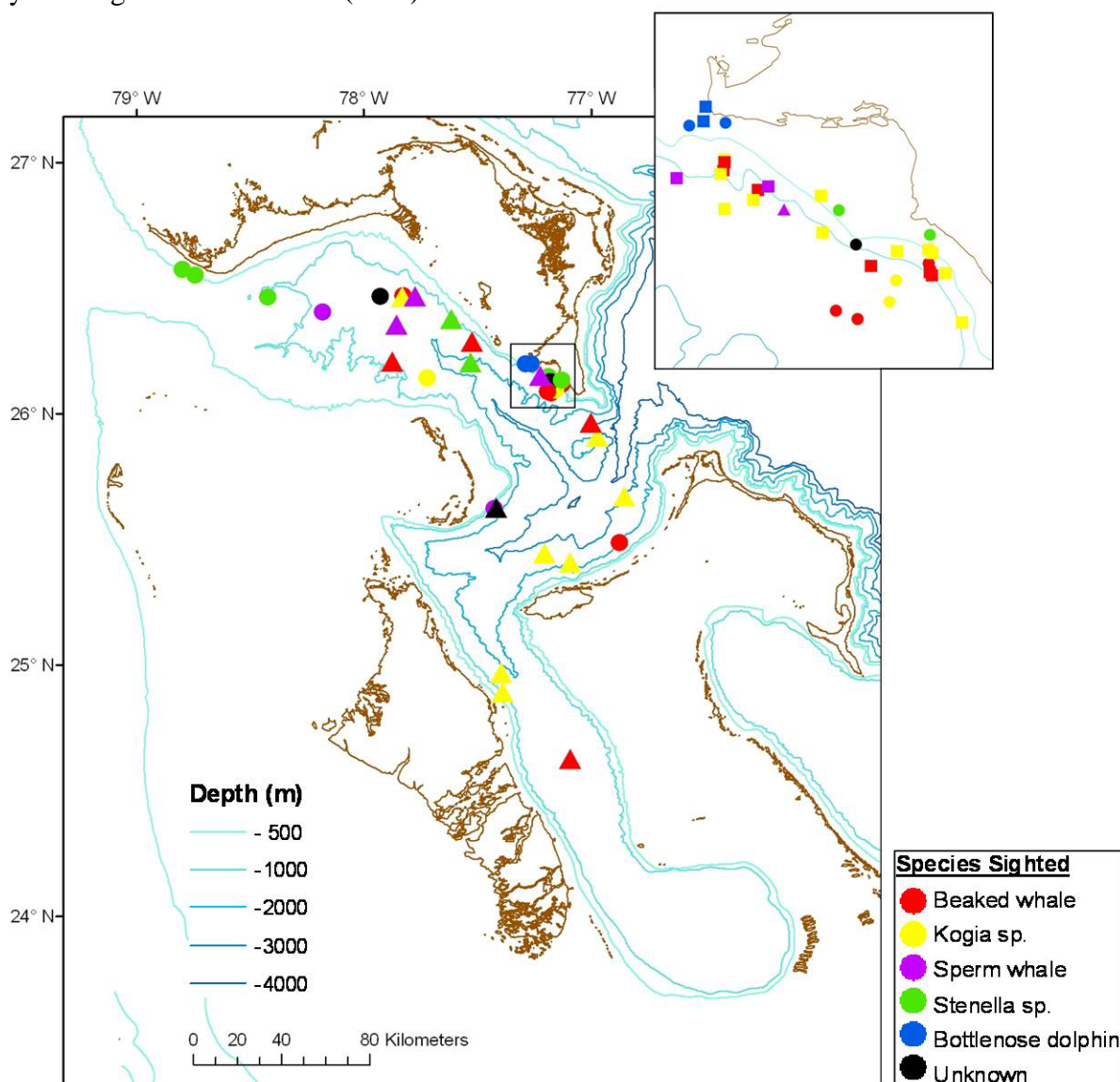
**Table 1. List of the cetaceans sighted during the Odyssey cruise in May – June 2007, showing the number of sightings, median and range of group sizes and the total number of animals seen.**

Species	No. of sightings	Group Size Median	Group Size Range	Total No. of Animals
Blainville's beaked whale ( <i>Mesoplodon densirostris</i> )	6	3.5	3 – 5	23
Cuvier's beaked whale ( <i>Ziphius cavirostris</i> )	1	3.0	3 – 3	3
Unknown Ziphiid species	2	2.0	1 – 3	4
Sperm whale ( <i>Physeter macrocephalus</i> )	5	1.0	1 – 6	10
Dwarf sperm whale ( <i>Kogia sima</i> )	5	1.0	1 – 3	8
Pygmy sperm whale ( <i>Kogia breviceps</i> )	3	1.0	1 – 2	4
Unknown <i>Kogia</i> species	3	2.0	1 – 2	5
Pan-tropical spotted dolphin ( <i>Stenella attenuata</i> )	5	10.0	4 – 25	62
Atlantic spotted dolphin ( <i>Stenella frontalis</i> )	2	13.0	12 – 14	26
<i>Stenella</i> sp.	1	1.0	1 – 1	1
Atlantic bottlenose dolphin - coastal ecotype ( <i>Tursiops truncatus</i> )	2	3.0	3 – 3	6
Unknown Delphinid species	1	1.0	1 – 1	2
Unknown small cetacean	1	2	2 – 2	2

The spatial distribution of sightings made during the *Odyssey* cruise while on transect lines and during other survey modes is shown in Figure 3. The majority of sightings were in NW Providence Channel which reflects the additional effort in that area. There is a cluster of sightings off the southwest coast of Abaco Island where the *Odyssey* remained for 3 days working in the lee shore which provided



increased opportunities for finding animals. Figure 3 also shows the distribution of sightings during the biopsy training off Abaco Island (inset).



**Figure 3.** Locations of cetacean sightings during the Odyssey cruise. Sightings made while running transect lines are represented by triangles and sightings during all other survey modes are shown with circles. The enlarged area is off the southwest coast of Abaco Island where biopsy training took place, with sightings shown with squares. The Odyssey also worked in this area for 3 days taking advantage of the lee shore which increased the number of sightings here relative to elsewhere during the survey.

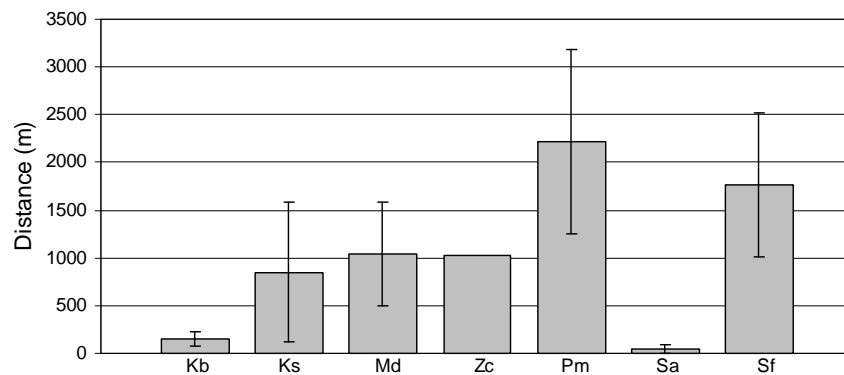
## RESULTS

The first year of this three-year effort has been completed, and although the project is in its infancy, the work completed thus far has produced meaningful results, but equally important, much has been learned. The first lesson is that the survey design employed works well to cover the deep-water habitats of the Canyon. Critically, a beaked whale species (*Mesoplodon densirostris*) was the most



frequently sighted cetacean species, demonstrating our ability to repeatedly detect beaked whales at sea. With the combination of the *Odyssey* cruise and the two additional surveys planned, the project will be able to identify “hot spots” showing preferred habitat for beaked whales.

Although sighting rates were low during the *Odyssey* cruise, the data collected for the distances to sightings of each species will be useful in estimating detection functions (Figure 4). This is an essential parameter for estimating abundance and densities using Distance Sampling techniques (Buckland *et. al* 2001).



**Figure 4. Mean sighting distances to species seen during the *Odyssey* cruise. Standard error bars demonstrate large variability for most species. Sperm whales (*Pm*) were sighted at the greatest distances (mean = 2222 m), while pan-tropical spotted dolphins (*Sa*) were sighted at very close ranges (mean = 47 m) .**

Over 900 photo-identification photographs were taken during encounters and preliminary analysis of photographs of Blainville’s beaked whales has been completed for both the biopsy training time period and the *Odyssey* cruise. Of the 27 whales photographed, there were 22 different individuals, with 5 internal matches between encounters. Additionally, there were photographic matches of 11 individual beaked whales to those previously archived in BMMRO’s existing photographic catalogues from south Abaco Island (e.g. Figure 5). “New” whales were found in Tongue of the Ocean and Northwest Providence Channel, as well as off the southwest coast of Abaco Island. These data will contribute towards estimating beaked whale abundance using mark-recapture techniques, examining rates of immigration and emigration and understanding their population structure in the Great Bahama Canyon.



**Figure 5.** *Md094, an adult female Blainville's beaked whale was first seen by BMMRO in 1998 (top) and resighted from the Odyssey on 5 June 2007 (bottom). The arrows point to scars from cookie cutter shark bites which serve as long-term marks to confirm the photo-identification match. She was seen again on 11 June 2007, at which time a biopsy sample was obtained.*

## **IMPACT/APPLICATIONS**

Beaked whales of the family *Ziphiidae* are perhaps the least known of marine mammals. Rarely sighted at sea, several species are known only from dead stranded specimens (Mead 1989). Recent mass strandings of beaked whales in several areas (Simmonds and Lopez-Juraco 1991; Frantzis 1998; Jepson *et al.* 2003), including the northern Bahamas (Balcomb and Claridge 2001, NOAA 2001) have correlated with international naval operations, raising concern that beaked whales may be particularly vulnerable to anthropogenic noise. The US Navy has two operating areas within the Great Bahama Canyon: the Atlantic Underwater Test and Evaluation Center and the Shallow Water range in the northern Berry Islands. As such, information on the basic population ecology of beaked whales in these areas and adjacent waters is necessary to understand and mitigate the effects of naval activities. However, ecological studies of beaked whales are logistically difficult due to the challenges of reliably detecting beaked whales at sea. This project represents the first beaked whale survey specifically designed to understand their population ecology within a canyon system using multiple approaches such as visual and acoustic non-random surveys, photo-identification and biopsy sampling.

## **RELATED PROJECTS**

### **Behavior Response Study (BRS)**

This is a large, multi-national project in which responses of whales exposed to underwater sounds are measured to identify and mitigate their adverse effects. Phase I of the study took place in Tongue of the Ocean and was led by Dr. Ian Boyd (SMRU) as the Chief Scientist and holder of Bahamian research permit, and the Principal Investigator and holder of US permit was Dr. Brandon Southall (National Oceanographic and Atmospheric Administration (NOAA)). The project is supported by the

Office of Naval Research (ONR) and US Department of Defense (NAVSEA PEO IWS Mr. Joseph Johnson and OPNAV N45 Dr. Frank Stone). Diane Claridge is a co-Principal Investigator. Photo-identification data and tissue samples collected during BRS will be contributed towards analysis of population structuring of beaked whales in the Great Bahama Canyon.

## **Dolphins and Whales of Abaco Island**

This project is a long-term field effort studying the distribution, occurrence and abundance of cetaceans off Great Abaco Island, in the northern Bahamas. The project has been funded by an annual grant from Earthwatch Institute since 1992 and is led by Charlotte Dunn and Diane Claridge (Bahamas Marine Mammal Research Organisation) as co-Principal Investigators. The weblink is:

<http://www.earthwatch.org/expeditions/claridge.html>. Photo-identification data and tissue samples collected during this project will be contributed towards analysis of population structuring of beaked whales in the Great Bahama Canyon.

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